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A COMPUTER MODEL FOR EVALUATING THE EFFECTS ON FIGHTING VEHICLE--ETC(U)
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A COMPUTER MODEL FOR EVALUATING THE EFFECTS ON FIGHTING VEHICLE CREWMEMBERS OF EXPOSURE TO CARBON MONOXIDE EMISSIONS,

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Presented are the details of a computer model, developed from an empirical equation derived by several researchers, which predicts the instantaneous amount of carboxyhemoglobin (COHb) in the blood of a person based upon the amount of carbon monoxide (CO) respired during a sequence of exposure periods. The computer program is particularly useful in the analysis of CO toxic hazards as applied to crewmembers of enclosed fighting vehicles in that the predicted COHb levels provide the evaluator with the means to predict whether or not human performance may be compromised or the health

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20. ABSTRACT (Continued)

and safety of any crewmember jeopardized. An appendix provides the reader with both a complete program listing (FORTRAN IV) and a sample presentation of a hypothetical mission for tank crewmembers.

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A COMPUTER MODEL FOR EVALUATING THE EFFECTS ON FIGHTING VEHICLE CREWMEMBERS OF EXPOSURE TO CARBON MONOXIDE EMISSIONS

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January 1980

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CONTENTS

A COMPUTER MODEL FOR EVALUATING THE EFFECTS ON FIGHTING VEHICLE CREWMEMBERS OF EXPOSURE TO CARBON MONOXIDE EMISSIONS

INTRODUCTION

The computer model described in this report was developed in December 1978 for use in analyzing data collected during Development Test II of the XM1 Main Battle Tank. The model was developed from an empirical equation (derived from reference 1 and detailed in reference 3) which predicts the amount of carboxyhemoglobin (COHb) in the blood of a person based upon both the cumulative COHb level prior to a period of exposure and the amount of carbon monoxide (CO) actually respired during the exposure. The amount of CO respired is a function only of the concentration level, the time duration of the exposure and the workload of the exposed individual during the period of exposure. Reference 3 explains that the percentage of COHb in a person's blood is the measure most closely related to the effects of CO exposure and that accounting for only CO exposure is unrealistic in that its effect upon both health and human performance are not adequately predicted based upon the evaluation method (4) and governing standards (2) presently used.

The computer program, described in the sections which follow, offers the evaluator a useful tool for determining whether or not a mission, comprised of numerous mission elements, can be accomplished without compromising system effectiveness or crew health and safety due to crew exposure to CO. The computer model is applicable to either the steady state or transient type exposure to CO. The steady state exposure is one of almost constant level (usually a value of less than 50 parts per million [ppm]) over a long time period such as the driver or passengers in a truck, traveling with a convoy, might experience. The transient type exposure is usually of short duration (2-3 minutes) as might result from firing weapons from either a stationary or moving vehicle (e.g., tanks, aircraft, armored personnel carrier). The crews of an artillery battery may also experience a transient type exposure to CO.

In the present case, the computer model calculates the instantaneous COHb blood content for each crew member (commander, driver, loader, gunner) at any time during the course of a mission. The calculated values of COHb can then be compared with the proposed limit values (3) (or alternate criteria) to determine what effects, if any, result from actual or projected exposures to CO.

The recommended limit for the COHb blood content (see reference 3 "Proposed Evaluation Scale") for the soldier population is 10 percent providing that the limit value is reached only occasionally. If exposure to a CO environment of greater than 50 ppm is a regular occurrence, the COHb average should not exceed 5 percent. Adherence to this evaluation scale should not compromise the health or safety of the soldiers, nor cause a decrement in crew performance.

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EQUATION FOR DETERMINING PERCENT COHb IN BLOOD

The following equation is used in the computer mode to predict the COHb blood content of each crewmember at any time during a mission:

$$COHb_t = COHb_o \{ e \exp - (t/2398B) \} + 218\{1 - e \exp - (t/2398B)\} \times \{.007B + (ppm\ CO/1316)\}$$

where $COHb_o$ = percentage of COHb in the blood at time o

$COHb_t$ = percentage of COHb at time t (t in minutes)

$B = 1/D_L + (P_B - 47)/V_A$ where

D_L = rate of diffusion of CO in the lungs

P_B = barometric pressure in millimeters of mercury

V_A = minute respiratory volume in milliliters

The term B is related directly to the physical exertion of the crewmember during the exposure period. For ease of application, the work effort has been simplified to five individual levels which are then related to D_L and V_A, the respiratory factors in the above equation. Table 1 defines the values of D_L and V_A.

TABLE 1

Definition of Values D_L and V_A

Work Effort	D_L	V_A
1. (Sedentary)	30	6000
2.	35	12000
3. (Light work)	40	18000
4.	50	24000
5. (Heavy work)	60	30000

COMPUTER PROGRAM DETAILS

General

The program was written specifically for application to the XM1 tank crew consisting of the commander, driver, loader and gunner, but it can be modified easily to be applicable to the crew of any surface vehicle or airplane by revising the column format (of the printout) to conform to the user's requirements. The program is written in the FORTRAN IV language and is usable with most digital computers. The complete program listing and printout of a sample problem are presented in the appendix.

Program Symbology Identification and Definitions

COHb1 -Program Name/Title

COO -Percentage of COHb in crewmember's blood at beginning of any mission segment, (input value at mission start).

COHBT -Cumulative percentage of COHb in crewmember's blood at the conclusion of any mission segment. Note that COHBT for any mission segment n, equals COO for segment n + 1.

PPM -Average carbon monoxide exposure level in parts per million, for any mission segment of time duration TI, in minutes. (Input data for each mission segment.)

IBWS -Work stress level for a crewmember for any mission segment (input data - integer [1, 2, 3, 4 or 5]).

DL -Rate of diffusion of CO in the lungs (input constants [real] [30, 35, 40, 50 or 60]) that is a function of work stress level.

VA -Minute respiratory volume in milliliters (input constants [real] [6000, 12000, 18000, 24000 or 30000]) that is a function of work stress level.

B -Calculated value of the work stress parameter that is a function of DL, VA and PB.

PB -Barometric pressure in millimeters of mercury.

TI -Time duration (minutes) of any mission segment.

HDR -Header (see detailed description below).

Header Details

The purpose of the header (HDR) is to provide the user with a heading (at the top of each page of computed/listed values) which describes (using up to 80 characters of alphanumeric) the mission scenario for the particular computations being made. In addition, HDR includes the column titles which identify both the input data (listed for convenience) and the calculated results. The column titles included CUM TIME (cumulative mission segment time) in HRS (hours) and MIN (minutes), D-TIME (mission segment time) in minutes, WE (level of work effort), CO-PPM (the CO exposure value) in parts per million, D-COHB (the calculated incremental value of COHb for each mission segment) in percent, T-COHB (the calculated cumulative value of COHb at the conclusion of any mission segment) in percent. The four column headings (i.e., WE, CO-PPM, D-COHB, T-COHB) are repeated for each crewmember. The program is written such that a maximum of 50 lines of calculations will be printed on each page.

Data Input Cards Format

The following are the formats for the input data cards:

Card Number	Symbol	Description	Card Column Numbers	Format
1	PB	Barometric Pressure	1-3	XXX
1	COO	$COHb_o$ (Commander)	5-8	X.XX
1	COO	$COHb_o$ (Driver)	10-13	X.XX
1	COO	$COHb_o$ (Loader)	15-18	X.XX
1	COO	$COHb_o$ (Gunner)	20-23	X.XX
2 thru (n-1)	TI	Exposure Time (min)	1-5	XXX.X
2 thru (n-1)	WE	Work Exposure (Commander)	7	X
2 thru (n-1)	PPM	CO Exposure (Commander)	9-13	XXXXX
2 thru (n-1)	WE	Work Effort (Driver)	15	X
2 thru (n-1)	PPM	CO Exposure (Driver)	17-21	XXXXX
2 thru (n-1)	WE	Work Effort (Loader)	23	X
2 thru (n-1)	PPM	CO Exposure (Loader)	25-29	XXXXX
2 thru (n-1)	WE	Work Effort (Gunner)	31	X
2 thru (n-1)	PPM	CO Exposure (Gunner)	33-37	XXXXX
Last Card[a]	WE	Work Effort (Commander)	7	X

[a]Note that the last data card should be punched either with a zero in column 7 or a negative 1 in columns 1 and 2 in accordance with the program logic (see card number 26 of the program listing in the appendix).

REFERENCES

1. Coburn, R.F., Forster, R.E., & Kane, P.G. Considerations for the physiological variables that determine the blood carboxyhemoglobin concentration in man. Journal of Clinical Investigation, 1965, 44, 1899-1910.

2. Department of Defense. Procedure for carbon monoxide detection and control in aircraft. MIL-STD-800, Naval Publications Center, Philadelphia, PA.

3. Steinberg, S., & Nielsen, G.D. A proposal for evaluating human exposure to carbon monoxide contamination in military vehicles. Technical Memorandum 11-77, US Army Human Engineering Laboratory, Aberdeen Proving Ground, MD, March 1977.

4. US Army Test and Evaluation Command. Toxic hazards tests for vehicles and other equipment. TOP 2-2-614, Aberdeen Proving Ground, MD, 17 January 1977.

APPENDIX

PROGRAM LISTING AND SAMPLE PRINTOUT

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Program [illegible] and Sample Printout

This appendix present [illegible] listing of Program COHBI, written in the FORTRAN IV language, and a [illegible] the sample problem given in reference 3 (Appendix [illegible]

[illegible] Program COHBI - 52 Punched Cards

```
          PROGRAM [illegible],TAPE5=INPUT,TAPE6=OUTPUT)
           DIMENSION COO [illegible], COHBT(4),PPM(4),IBWS(4),DL(5),
          1          [illegible],B(5)),HDR(80),DCOHB(4)
           DATA          DL/30.0,35.0,40.0,50.0,60.0/,
          1       [illegible],12000.0,18000.0,24000.0,30000.0/
    100    READ     (5,110)  HDR,PB,COO
    110    FORMAT  (80A1/F3.0,4(1X,F4.2))
           TIME = 0.0
           HTIME = 0.0
    290    WRITE (6,300) HDR,PB
    300    FORMAT (1H1,'SCENARIO. ',80A1/
          1         20X,'BAROMETRIC PRESSURE =',F6.1,' (MM HG)'//
          2         T4,'CUM TIME',T15,'D-TIME',
          3         T23,'--- --- COMMANDER ---------',
          4         T51,'--------- DRIVER  ----------',
          5         T79,'-------- --- LOADER -----------',
          6         T107,'------- --- GUNNER -------------'/
          7         T3,'HRS',T10,'MIN',T17,'MIN',
          8         4('    WE CO-PPM  D COHB  T-COHB')/)
           WRITE  (6,350)  HTIME,TIME,COO
    350    FORMAT (1X,F5.2,1X,F6.1,1X,4(19X,F8.2,1X))
           DO  400  I = 1,5
    400    B(I) = 1.0/DL(I) + (PB-47.0)/VA(I)
    500    READ   (5,510) TI,(IBWS(J),PPM(J),J=1,4)
    510    FORMAT (F5.1,4(1X,I1,1X,F5.0))
           IF (TI.LT.0..OR.IBWS(1).EQ.0.)  GO TO 715
           IF (TI .EQ. 0.0) GO TO 500
           DO  600 K = 1,4
           TERM = EXP(-TI/2398./B(IBWS(K)))
           COHBT(K) = COO(K)*TERM + 218.0*(1.0-TERM)*(0.007*B(IBWS(K))
          1+PPM(K)/1316.0)
    600    DCOHB(K) = COHBT(K) - COO(K)
           DO 650 L = 1,4
    650    COO(L) = COHBT(L)
           TIME = TIME + TI
           HTIME = TIME/60.0
           LINES = LINES + 1
           IF (MOD(LINES,50) .EQ.0) WRITE (6,675)HDR
    675    FORMAT (1H1,'SCENARIO. ',80A1 /
          1         T4,'CUM TIME',T15,'D-TIME',
```

Listing of Program COHB1 (Continued)

```
           2       T23,'-------- COMMANDER -------',
           3       T51,'--------- DRIVER ---------',
           4       T79,'--------- LOADER ---------',
           5       T107,'--------- GUNNER ---------'/
           6       T3,'HRS',T10,'MIN',T17,'MIN',
           7       4('   WE CO-PPM  D-COHB  T-COHB')/)
            WRITE  (6,700) HTIME,TIME,TI,
           1(IBWS(M),PPM(M),DCOHB(M),COHBT(M),M=1,4)
     700    FORMAT (1X,F5.2,1X,F6.1,F7.1,4(I4,F8.0,F7.2,F8.2,1X))
     710    GO TO 500
     715    STOP
     720    END
```

SAMPLE PRINTOUT

SCENARIO: (IDENTIFYING HEADING FOR COHB CALCULATION)-VERIFY TM 11-77 EXAMPLE
BAROMETRIC PRESSURE = 760.0 (MM HG)

CUM TIME		D-TIME	COMMANDER				DRIVER				LOADER				GUNNER			
HRS	MIN	MIN	WE	CO-PPM	D-COHB	T-COHB	WE	CO-PPM	D-COHB	T-COHB	WE	CO-PPM	D-COHB	T-COHB	WE	CO-PPM	D-COHB	T-COHB
0.00	0.0					1.00				.50				1.00				2.00
3.00	180.0	180.0	3	20.	1.66	2.66	2	20.	1.69	2.19	1	20.	.99	1.99	5	20.	1.16	3.16
3.17	190.0	10.0	5	20.	.07	2.73	2	20.	.06	2.25	1	20.	.04	2.03	5	20.	.02	3.18
3.18	191.0	1.0	4	1500.	2.05	4.78	2	1500.	1.16	3.41	1	1500.	.68	2.71	5	1500.	2.52	5.70
3.20	192.0	1.0	4	700.	.93	5.71	2	700.	.53	3.95	1	700.	.31	3.02	5	700.	1.13	6.83
3.21	192.5	.5	4	100.	.05	5.76	2	100.	.03	3.98	1	100.	.02	3.04	5	100.	.05	6.88
3.22	193.0	.5	4	50.	.01	5.77	2	50.	.01	3.99	1	50.	.01	3.05	5	50.	.01	6.89
3.38	203.0	10.0	5	35.	.01	5.78	2	35.	.09	4.08	1	35.	.08	3.13	5	35.	-.10	6.79
6.38	383.0	180.0	3	20.	-1.62	4.15	1	20.	-.21	3.87	2	20.	.18	3.31	3	20.	-2.32	4.47
6.55	393.0	10.0	5	20.	-.08	4.08	1	20.	-.01	3.86	2	20.	.01	3.32	3	20.	-.07	4.40
6.57	394.0	1.0	4	1500.	2.04	6.12	1	1500.	.67	4.53	2	1500.	1.16	4.48	3	1500.	1.57	5.97
6.58	395.0	1.0	4	700.	.92	7.04	1	700.	.31	4.84	2	700.	.53	5.00	3	700.	.71	6.68
6.59	395.5	.5	4	100.	.04	7.08	1	100.	.02	4.85	2	100.	.03	5.03	3	100.	.03	6.71
6.60	396.0	.5	4	50.	.01	7.08	1	50.	.01	4.86	2	50.	.01	5.04	3	50.	.01	6.72
6.77	406.0	10.0	5	35.	-.12	6.96	1	35.	.03	4.89	2	35.	.04	5.08	3	35.	-.05	6.67
9.77	586.0	180.0	3	20.	-2.44	4.52	3	20.	-1.02	3.87	5	20.	-1.44	3.64	1	20.	-1.22	5.45
9.93	596.0	10.0	5	20.	-.11	4.41	3	20.	-.03	3.85	5	20.	-.03	3.62	1	20.	-.05	5.40
9.95	597.0	1.0	4	1500.	2.04	6.45	3	1500.	1.57	5.42	5	1500.	2.51	6.13	1	1500.	.67	6.07
9.97	598.0	1.0	4	700.	.92	7.37	3	700.	.71	6.13	5	700.	1.13	7.26	1	700.	.30	6.37
9.98	598.5	.5	4	100.	.04	7.40	3	100.	.03	6.17	5	100.	.05	7.30	1	100.	.01	6.38
9.98	599.0	.5	4	50.	.00	7.41	3	50.	.01	6.17	5	50.	.01	7.31	1	50.	.00	6.38
10.15	609.0	10.0	5	35.	-.15	7.26	3	35.	-.02	6.16	5	35.	-.14	7.17	1	35.	-.01	6.38

This sample printout from program COHB1 is related directly to the sample problem given in Appendix B of reference 3. The printout for the "Commander" duplicates the specific problem given as Table 1B (reference 3). The calculated values of COHb (in percent) in the above printout match exactly those given in the reference.

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